# SD0716 Energy Harvesting


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# E-FAD: Electric Field Activation Detector

- Voltage too low to be harvested

Solution:

- Low – Powered Sensing Device

- Appropriate Transmitters

Efficient and reliable sensor

# Flashback

Objectives:

- E-field detection
- Harvest Energy
- Use the harvested energy
- Send data using RF-Transmitters
- Substation communication
- Efficient & Reliable

# This Semester

1'st

May'08

- Active E-Field Sensor
- Updated Sensing circuitry
- Testing Equipment & Field Tests
- Added Networking Capabilities
- Expanded Options
- Configured Communication Scheme
- Bonus: Handheld

# Why E-Field ?

E-Field
V/s
EM-Field

Two main ideas:

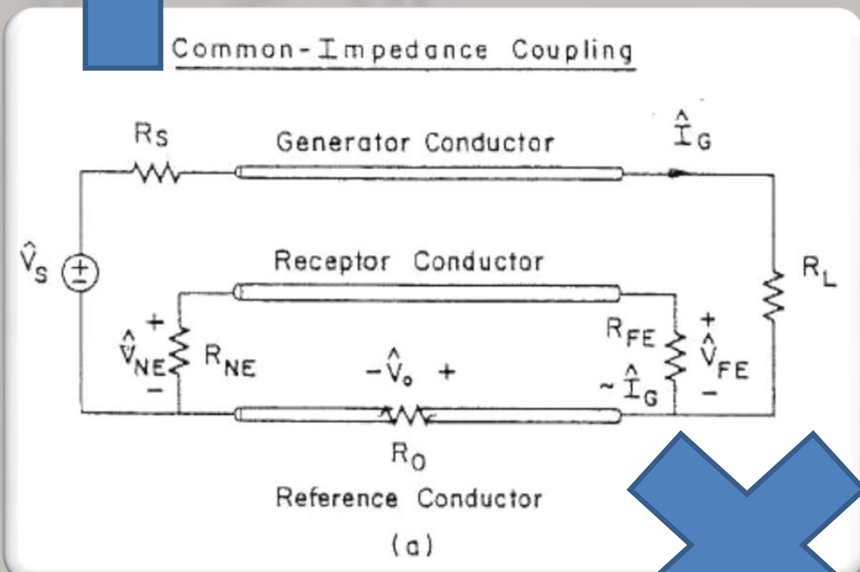
- **Detect E-field**
- **Detect Electro-Magnetic field**

- *Electro-Magnetic field* depends on the *current* i.e. the line loading,

- Varies a lot (negligible during nights)

Therefore, *E-field* - a good and reliable sensing agent

# Calculations



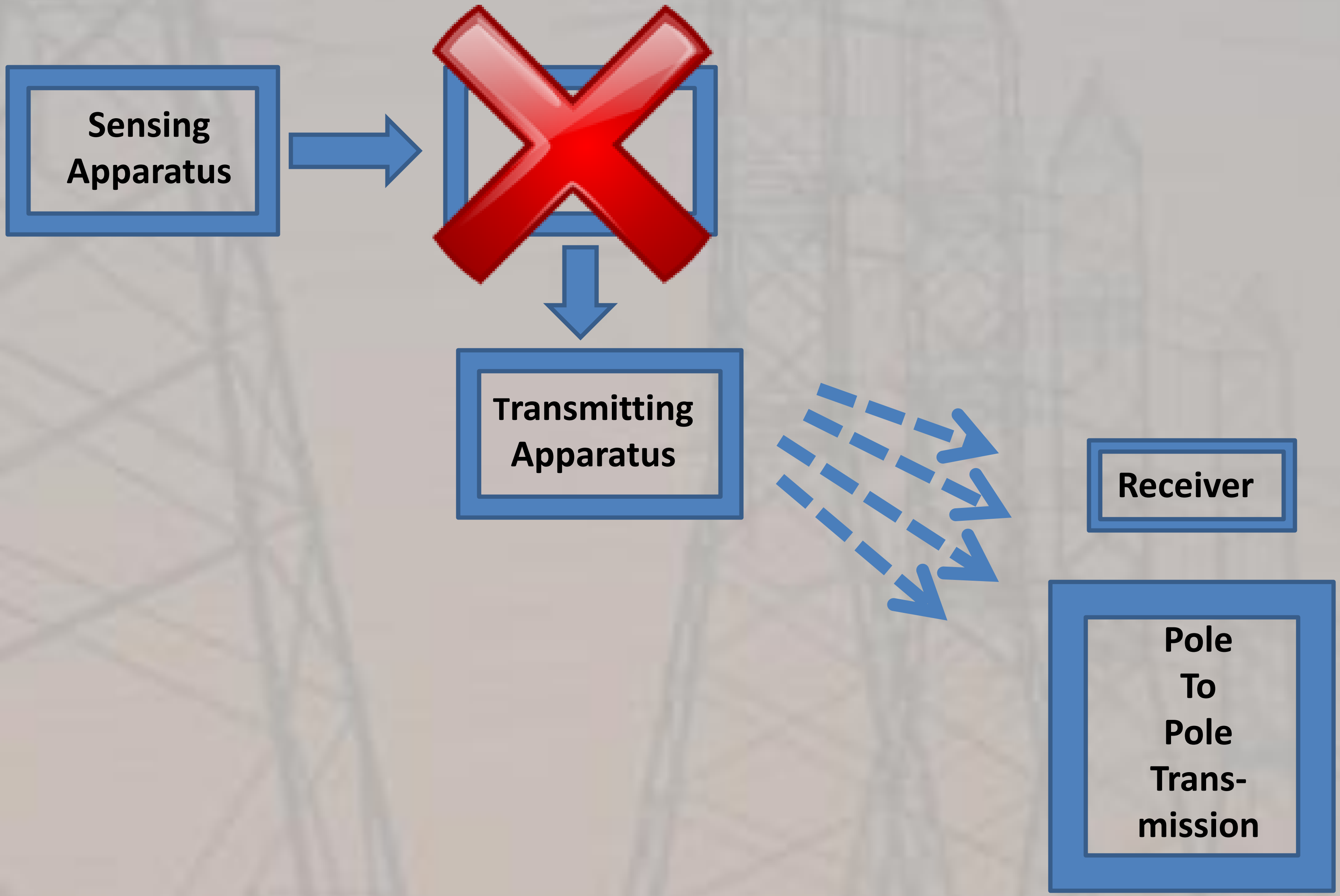

- How much energy can be harvested?

- Depending on
  - Distance (line to sensor)
  - Transmission characteristics and sensor dimension.

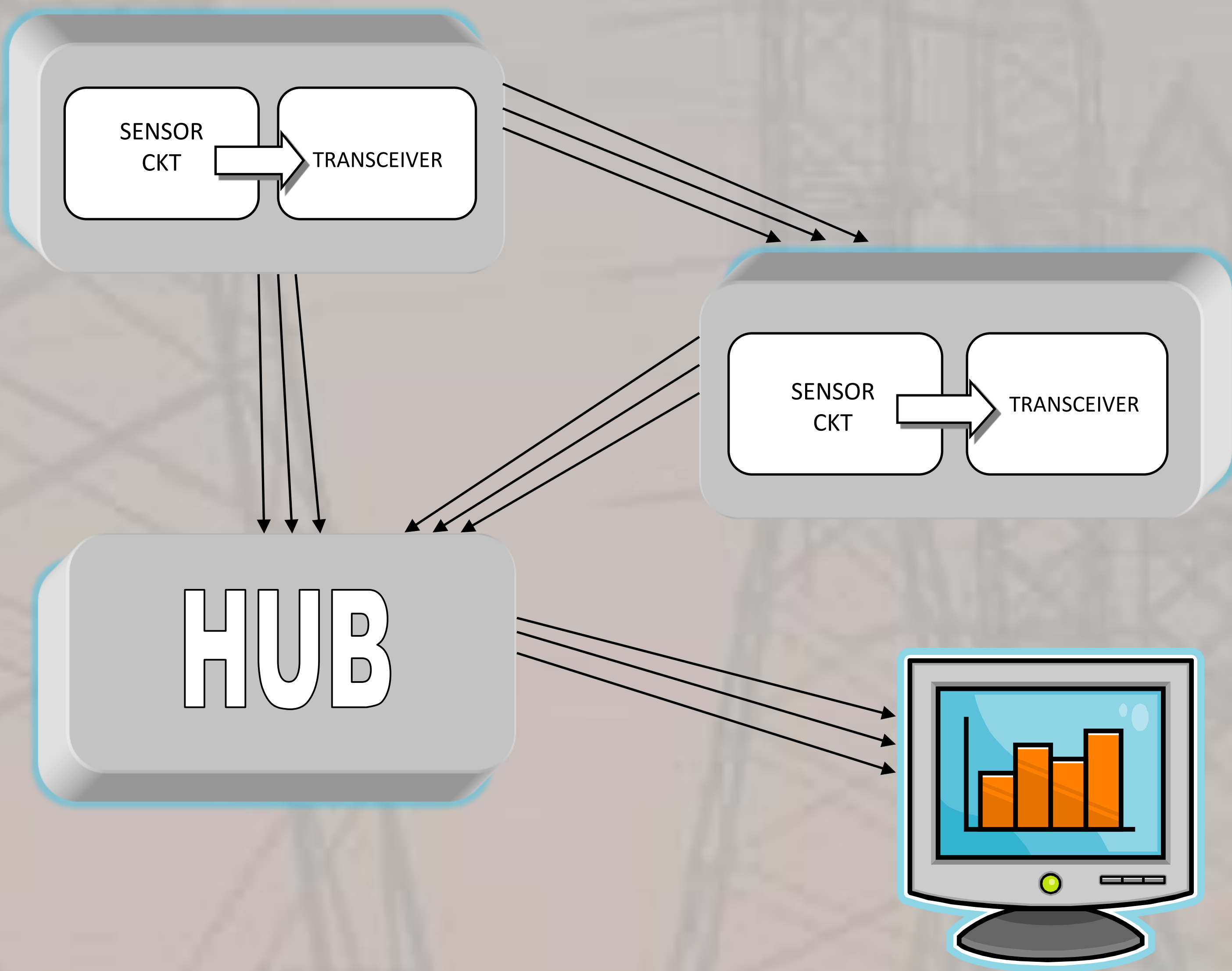
- Disappointing
  - Sensor (rod shaped),
  - A meter long
  - Harvest only about **4mV**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | pi = | 3.14159 | | | |
| Capacitance between 2 wires | | | | Capacitance between wire and ground | | | | ε = | permittivity of air | | 8.85E-12 | |
| | ((pi)ε) | | | | (2(pi)ε) | | | h = | dist from conductor (km) | | 0.001 | (1m) |
| C = | cosh^(-1) (h/b) | | | C = | cosh^(-1) (h/b) | | | b = | radius of wire (km) | | 0.000006 | (6mm) |
| | | | | | | | | w = | 2*pi*f | | 376.9911184 | |
| C = | 4.78836E-12 | | | | | | | jw = | 376.991118430775j | | | |
| | | | | | | | | Rne = | 1.00E+06 | | | |
| Voltage Near End(ne) Far End(fe) | | | | | | | | Rfe = | 1.00E+25 | | | |
| | | | | | | | | RL = | 400+1000j | | | |
| Vne = | jw(Mne(cap)) | | | | | | | Rs = | 300+750j | | | |
| Vs | | | | | | | | Ro = | 0 | | | |
| | | | | | | | | Mne(cap) = | 2.73620832770679E-06+ | | | |
| | Vne = | -1.152117281788E-18+0.001031 | | | | | | | | | | |
| | Vs | | | | | | | Mne(ci) = | 0 | | | |
| | Vfe = | -1.152117281788E-18+0.001031 | | | | | | Mfe(ci) = | 0 | | | |
| | Vs | | | | | | | | | | | |
| | | | | | | | | Vs = | 4.16E+03 | | | |
| | Vne = | -4.78926160381347E-15+4.2879 | | | | | | | | | | |
| | Vfe = | -4.78926160381347E-15+4.2879 | | | | | | | | | | |
| | | | | | Vne | mag. = | 4.287974047 | | V/km | | | |
| | | | | | | | | 4.287974E-03 | V/m | | | |

# Block Diagram (1)



# Block Diagram (2)



# Problems Faced

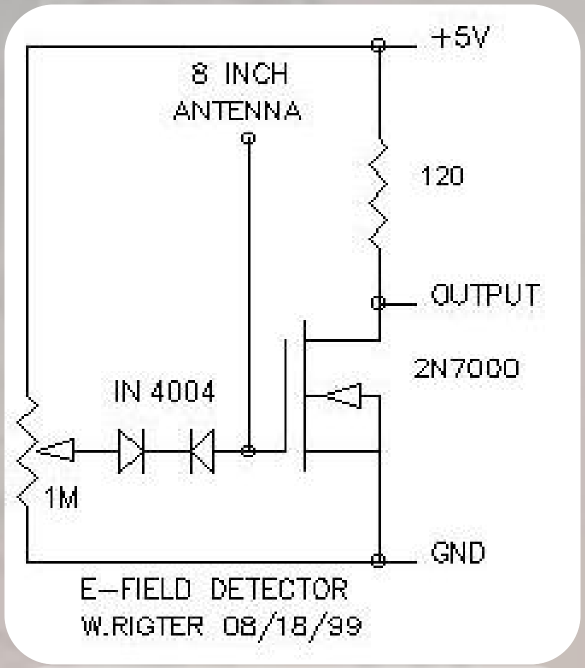
HIGH
VOLTAGE

- Unstable MOSFET
- 110 V - inaccurate
- Field testing
- PCB Interference

# Updated Design Requirements

- *E-field* Detection
- Does Not rely on current (loading)
- Works independently
- Should withstand the *diverse weather conditions*
- Small amount of power usage
- Ability to send correct information
- Test circuit on High Voltage lines
- Develop handheld device

# The Circuit Diagram




- **MOSFET** - switch
- **~~1N4004~~ 1N4148 Diodes** – better ESD protection
- **1Meg Trimmer** – Active/Saturation region
- **Antenna** – Charge collecting plate
- **Increased the Impedance**
- **Capacitors**

# Sensor(Antenna)

**The Charge Collecting Plate**

**The Research** - experiments

- E-field accumulates at edges
- More edges = More E-field
- Any material

**Current Design**

- Braided Mesh Net
- Cone Shaped
- With many edges

# Field Test

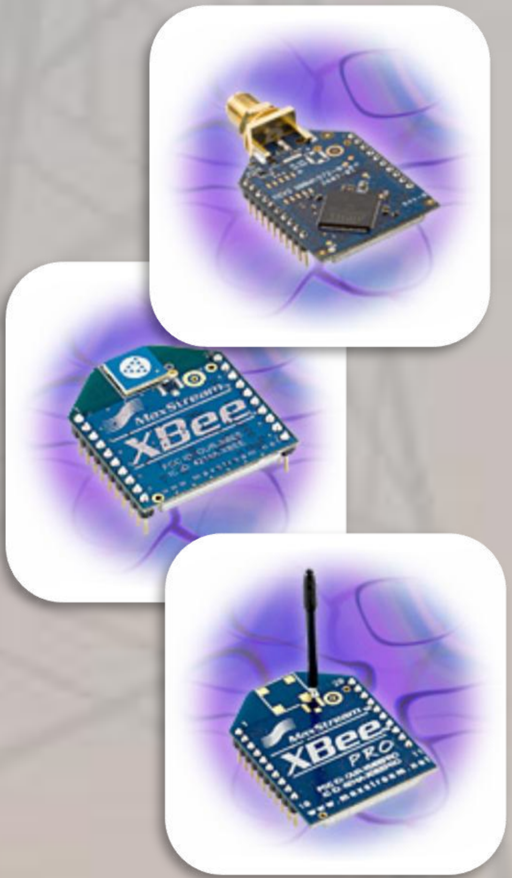
| | | | | |
|---|---|---|---|---|
| Field Test - NDSU E-FAD sensor test | | | | |
| | | | | |
| Moorhead Public Service, Dave Kahly - Electric Division Manager, Randy Lake - Lineman | | | | |
| | | | | |
| <u>Wire Identification</u> | <u>Amps</u> | <u>Voltage</u> | <u>mgauss</u> | <u>Distance for Steady Light</u> |
| 3-phase line on 8' arm | 35 | 12.47kV | 35 | 46 inches |
| 3-phase line on Anderlite brackets | 214 | 12.47kV | 100 | 66 inches |
| Single phase | 12 | 7,200 | 35 | 96 inches |
| 3-phase with single phase underground | - | 115kV | 9 | 30 1/2 feet |

# Field Test





# XBee RF-Module




- Long range (100-300ft)
- Low Power
- Advanced Networking & Security
- ADC and I/O line support
- Easy Configuration
- Antenna options
- Worldwide Acceptance, FCC Approval (USA)

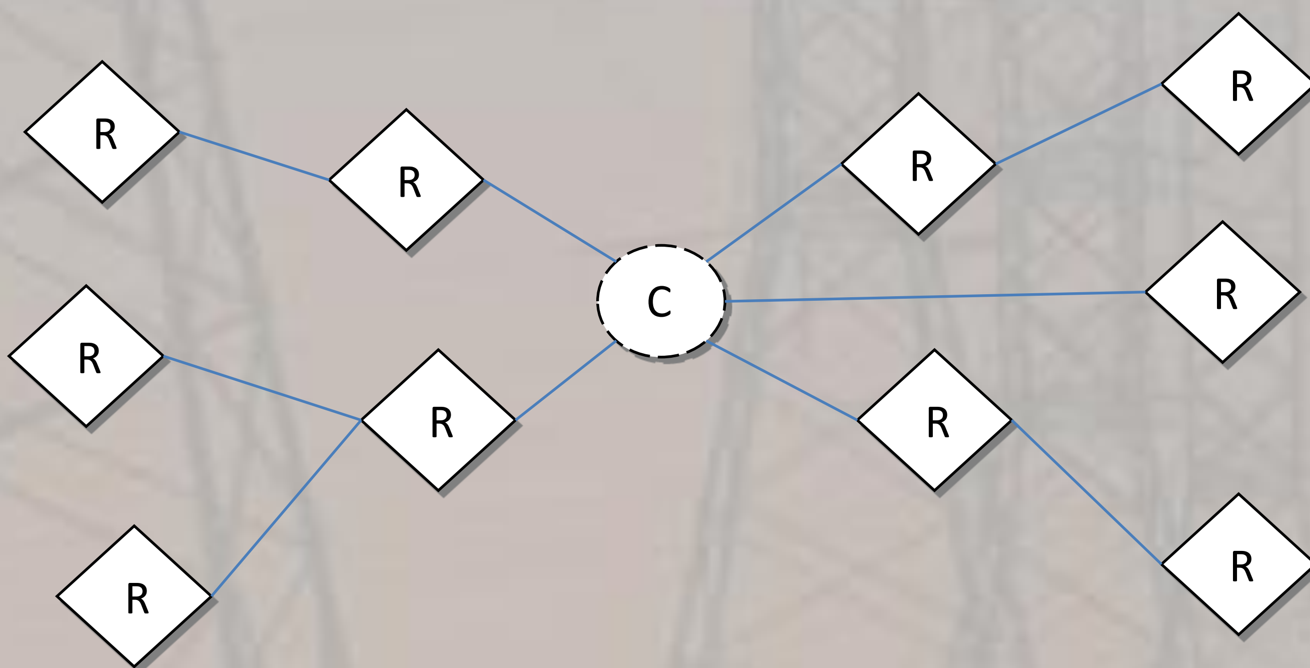
# XBee RF-Module

C

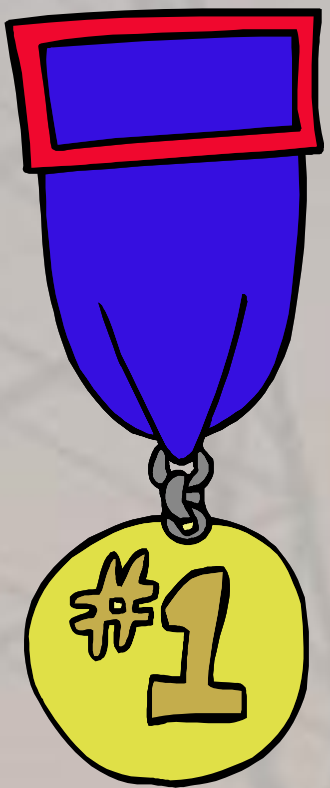
**Coordinator:**
One per PAN (network),
Organizes and manages a PAN

R

**Router:**
Many in numbers,
Responds to the Coordinator

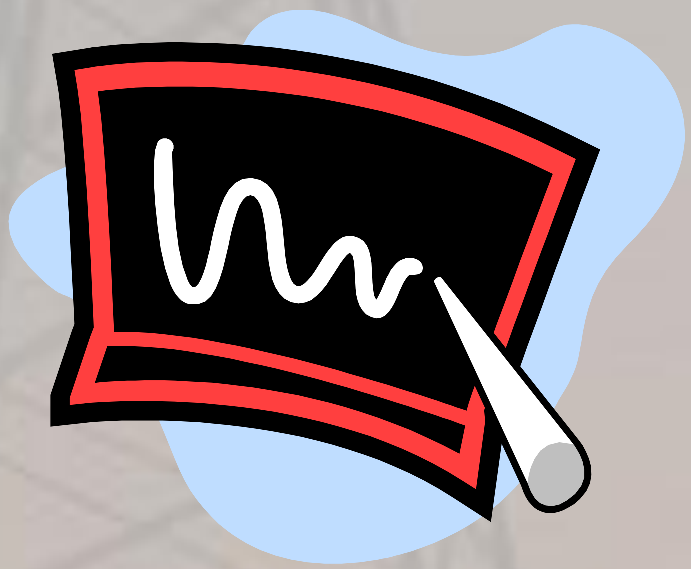


# Achievements




- Testing Equipment
- Field Test
- Communication
- Integration
- PIC & LCD
- Breadboards
- PCBs
- Enclosures

# Setbacks



- Method of testing
- Calculations
- Field test
- Transceiver selection
- PIC-code
- Troubleshooting
  - DC/DC conv.
  - Noise

# Lessons Learned

- More research
- Time Management
- Priorities
- Parts ordering
- Testing
- PCB EMC an issue
- Not ideal experimental conditions

# Future Works


- Filter (only 60Hz)
- Rectifier (pure DC)
- Solar powered
- Optimization
- Data acquisition
- Mobile phone network
- Passive

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